KLOE RESULTS ON $f_0(980)$, $a_0(980)$ SCALARS AND η DECAYS

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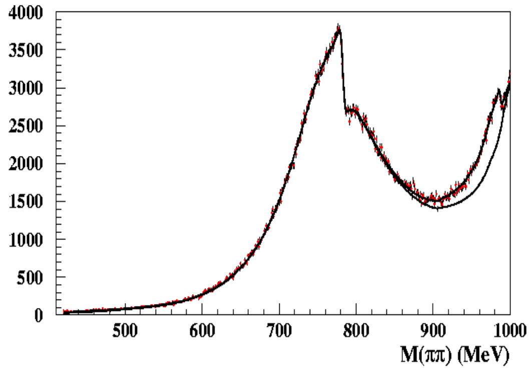
The KLOE experiment running at the ϕ-factory DAΦNE has collected ~ 450 pb^{-1} in the 2001–2002 data taking. We report preliminary results on light meson spectroscopy based on this data sample; particles are all produced through ϕ radiative decays. The nature of $f_0(980)$ and $a_0(980)$ is investigated by studying the shape of the resulting mass spectra, which is sensitive to their structure. A detailed study of the $\eta \to \pi\pi\pi$ dynamics through a Dalitz plot analysis gives the possibility to extract information on the quark mass difference. Finally, the branching ratio for the $\eta \to \pi^0\gamma\gamma$ decay is compared with previous measurements and with the expectations from Chiral Perturbation Theory.



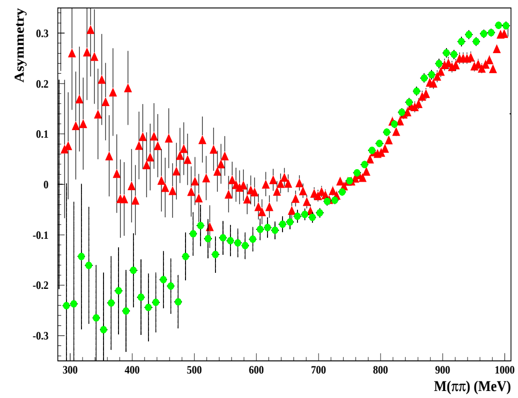


Figure 1: Left: two pion invariant mass for $\pi^+\pi^-\gamma$ events. The upper and lower curves are the result of the fit and the contribution due to FSR+ISR respectively. Right: forward-backward asymmetry as a function of $M_{\pi\pi}$. Experimental data are reported as dark triangles while light dots represent the Monte Carlo expectations for FSR and ISR only.

1 Introduction

The KLOE experiment [1] operates at DAΦNE,[2] the Frascati e^+e^- collider, whose center of mass energy is equal to the ϕ mass. Data collected in 2001-2002, corresponding to ~ 450 pb^{-1}, are used to study light scalar and pseudoscalar mesons produced through ϕ radiative decays.

2 Light Scalar Mesons: f_0(980) and a_0(980)

A complete study of the radiative decay of the ϕ to the scalar mesons $f_0(980)$ and $a_0(980)$ is in progress, involving the decays $f_0 \to \pi^+\pi^-/\pi^0\pi^0$ and $a_0 \to \eta\pi^0$, with $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$. Since the mass spectra are sensitive to the nature of such mesons [3] which are still puzzling,[4,5,6] the data are compared with two different theoretical models. In the first one the scalar amplitude is described by the kaon-loop model [7] while in the second one a point-like approach is followed. In both cases, the interference with the background with the same final state is taken into account in the fit procedure.

For the $\pi^+\pi^-\gamma$ final state there is a huge irreducible background of $e^+e^- \to \pi^+\pi^-$ with an additional photon due to initial state (ISR) or final state radiation (FSR). However, requiring two tracks and a large angle photon a clean signal appears in the $M_{\pi\pi}$ region above 850 MeV (see Fig. 1.left). Moreover, a forward-backward asymmetry $A = \frac{N^+(\theta>90^\circ)-N^+(\theta<90^\circ)}{N^+(\theta>90^\circ)+N^+(\theta<90^\circ)}$ is expected due to the interference of FSR and ISR.[8] In Fig. 1.right we show this asymmetry as a function of $M_{\pi\pi}$, both for data and for theoretical predictions with ISR and FSR only. A clear discrepancy is observed in the f_0 region and in the mass range below 700 MeV, thus adding a further evidence on the need of a scalar meson in the theoretical description.

In the case of the $f_0 \to \pi^0\pi^0$ decay we instead deal with a non-resonant background with the same $\pi^0\pi^0\gamma$ signature, produced through $\omega\pi^0/\rho\pi^0$ intermediate states. The intensity of this background is twice the signal. In order to consider its interference with the scalar term we fit the Dalitz plot distribution. A smaller background contamination dominated by $\phi \to \eta\gamma$, with $\eta \to \pi^0\pi^0\pi^0$ and two lost or merged photons, is estimated by Monte Carlo and subtracted from the Dalitz plot. When using the kaon-loop model we cannot describe data without introducing a scalar term due to a $\sigma(600)$ meson.

For the fully neutral search of $\phi \to a_0\gamma$, the background with the same $\eta\pi^0\gamma$ final state is

Table 1: Fitted parameters of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot.

$\mathrm{N_{dof}}$	Prob(χ^2) (%)	a / d	b / e	c / f
147	60	$-1.072 \pm 0.006^{+0.005}_{-0.007}$	$0.117 \pm 0.006^{+0.004}_{-0.006}$	$0.0001 \pm 0.0029^{+0.0003}_{-0.0021}$
		$0.047 \pm 0.006^{+0.004}_{-0.005}$	$0.006 \pm 0.008^{+0.013}_{-0.000}$	$0.13 \pm 0.01^{+0.02}_{-0.01}$
149	63	$-1.072 \pm 0.005^{+0.005}_{-0.008}$	$0.117 \pm 0.006^{+0.004}_{-0.006}$	—
		$0.047 \pm 0.006^{+0.004}_{-0.005}$	—	$0.13 \pm 0.01^{+0.02}_{-0.01}$

small and simplifies the fit procedure. On the other hand, having a yield ten times smaller than the $f_0 \to \pi^0\pi^0$, it is contaminated by a large non-interfering background with a five photon signature. The a_0 decay chain with $\eta \to \pi^+\pi^-\pi^0$ has instead a rate three times smaller than the neutral channel, but it is completely background free. A combined fit of the two channels is in progress to extract the a_0 parameters.

3 Dynamics of $\eta \to \pi\pi\pi$

The amplitude of $\eta \to \pi\pi\pi$ is related to the d-u quark mass difference; a precise study of this decay can lead to a very accurate measurement of $Q^2 = (m_s^2 - \hat{m}^2)/(m_d^2 - m_u^2)$. Using the 17 millions η mesons produced in 2001/2002, the dynamics of both $\pi^+\pi^-\pi^0$ and $\pi^0\pi^0\pi^0$ final states has been studied through a Dalitz plot analysis. The η mesons are clearly tagged by detecting the monochromatic recoil photon of the $\phi \to \eta\gamma$ decay ($E_{\mathrm{recoil}} = 363$ MeV); the background is at the level of few per mill.

Concerning the $\pi^+\pi^-\pi^0$ final state, the conventional Dalitz variables are $X \propto T_+ - T_-$ and $Y \propto T_0$, where T is the kinetic energy of the pions. The measured distribution is parametrized as: $|A(X,Y)|^2 = 1+aY+bY^2+cX+dX^2+eXY+fY^3$. As expected from C parity conservation, the odd powers of X are consistent with zero (see Tab. 1). Using our fitted parameters, the value of Q can be extracted. For example, in Ref. 9 the value $Q = 22.8 \pm 0.4$ is obtained, the error being dominated by the $\eta \to \pi^+\pi^-\pi^0$ width. This value is in agreement with Chiral Perturbation Theory (χ_{PT}) predictions [10] and with other evaluations based on η decays, [11,12] which have larger errors.

For the $\eta \to \pi^0\pi^0\pi^0$ decay the Dalitz plot density is described by a single parameter α: $|A|^2 \propto 1 + 2\,\alpha\, z$, where z is related to the three pion energies in the η rest frame. Photons are paired to π^0's after kinematically constraining the total 4-momentum to M_ϕ, thus improving the energy resolution. By fitting a sample with high purity on pairing (98.5%), corresponding to an analysis efficiency of 4.5%, we get:

$$\alpha = -0.013 \pm 0.005_{\mathrm{stat}} \pm 0.004_{\mathrm{syst}}\,. \tag{1}$$

4 The $\eta \to \pi^0\gamma\gamma$ Decay

The $\eta \to \pi^0\gamma\gamma$ decay is an important test of χ_{PT} because of its sensitivity to p^6 on both the branching ratio (BR) and the $M_{\gamma\gamma}$ spectrum. [13,14] The present experimental situation is not completely clear: the most accurate determination of the BR [15] is far from theoretical predictions while a more recent measurement, [16] with a larger relative error, gives a significantly lower value. Moreover, all previous searches were done at hadron machines, using mainly $\pi^- p \to \eta\, n$. The value of the BR has decreased by three orders of magnitude in the last 40 years, due to the improved separation of the $\eta \to \pi^0\pi^0\pi^0$ background.

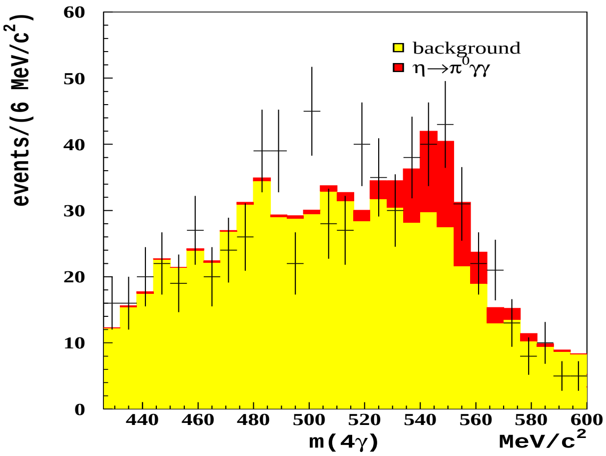


Figure 2: Four photon invariant mass for $\eta \to \pi^0\gamma\gamma$ events. Data (crosses) are fitted with the signal and background contributions evaluated from MC (solid histograms).

KLOE searches for this decay in a much cleaner environment, with different background topologies and experimental systematics. The two orders of magnitude higher background with the same five photon final state ($e^+e^- \to \omega\pi^0 \to \pi^0\gamma\pi^0$, $\phi \to f_0\gamma \to \pi^0\pi^0\gamma$, $\phi \to a_0\gamma \to \eta\pi^0\gamma$ with $\eta \to \gamma\gamma$) is reduced by vetoing the additional $\omega/\pi^0/\eta$ particles in the event. The remaining background is $\eta \to \gamma\gamma$ with additional clusters from shower fragmentation or machine background and $\eta \to \pi^0\pi^0\pi^0$ with merged/lost photons. We reject them with energy momentum conservation and a likelihood technique to identify merged clusters. The preliminary results obtained fitting the η invariant mass spectrum (Fig. 2) gives a BR in agreement with $\mathcal{O}(p^6)$ χ_{PT} calculations, with a central value which is three times smaller than the previous measurement:

$$\mathrm{BR}(\eta \to \pi^0\gamma\gamma) = (8.4 \pm 2.7_{\mathrm{stat}} \pm 1.4_{\mathrm{syst}}) \times 10^{-5}\,. \tag{2}$$

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